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Electrospinning Applications Air Filtration and Superhydrophobic Materials

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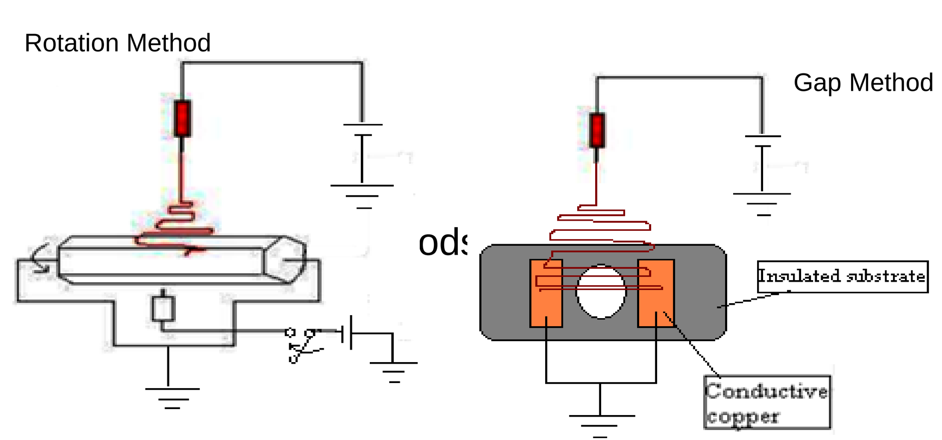
Introduction

Electrospinning is a technique that uses an electric field to draw polymer fibers and particles from its solution. Electrospun fibers can be deposited on a variety of substrates and use in various applications such as filtration media, tissue scaffolds, superhydrophobic materials, cosmetic skin masks, and electronic devices. In this project application of electrospinning in air filtration media and superhydrophobic material are discussed.

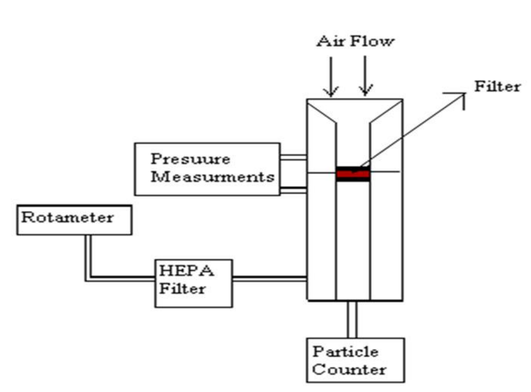
Filtration is a physical technique for separation. Highly efficient filtration media with the ability to capture nanosize particles are desirable and electrospinning has the capacity to generate fibers in micro and nanorange. This project aims to investigate filter performance of controlled electrospun fiber morphologies.

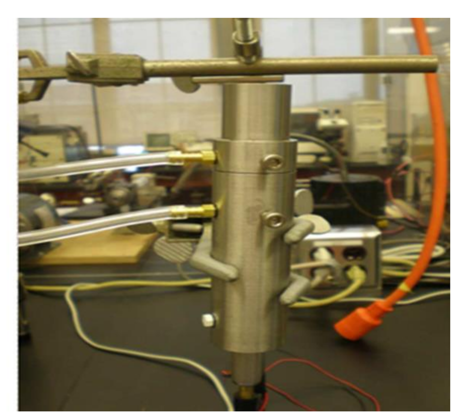
Superhydrophobic materials are highly water repellent materials with water contact angles ranging between 150̊ and 180̊. Hydrophobic materials can become superhydrophobic through addition of microstructure. This project investigates the tunability of electrospun fiber morphologies via electroactivation using a piezoelectric material.

Air Filtration

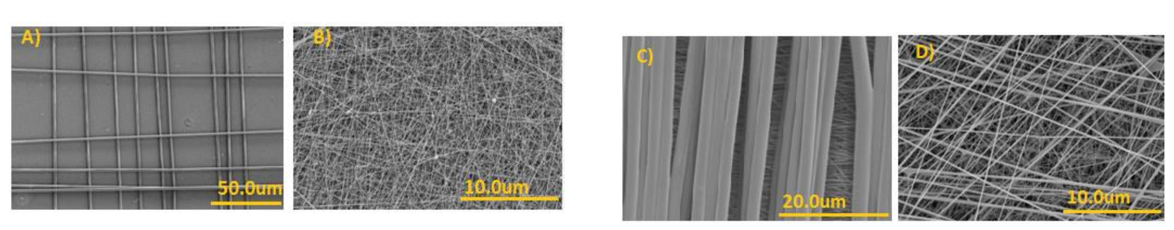


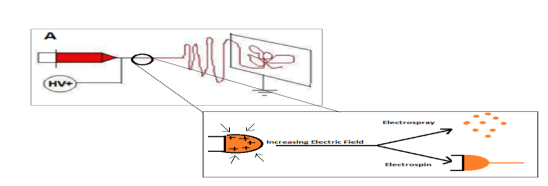
Custom-built filter performance testing apparatus:





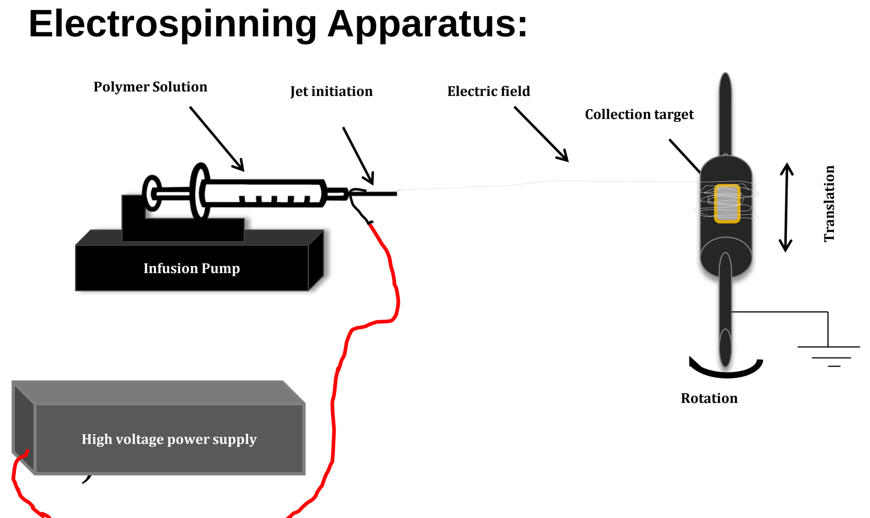
SEM images of electro-spun fibers of different polymers showing variety of morphologies A) Unimodal Orthogonal, B) Unimodal Random, C) Bimodal Orthogonal, and D) Bimodal Random.

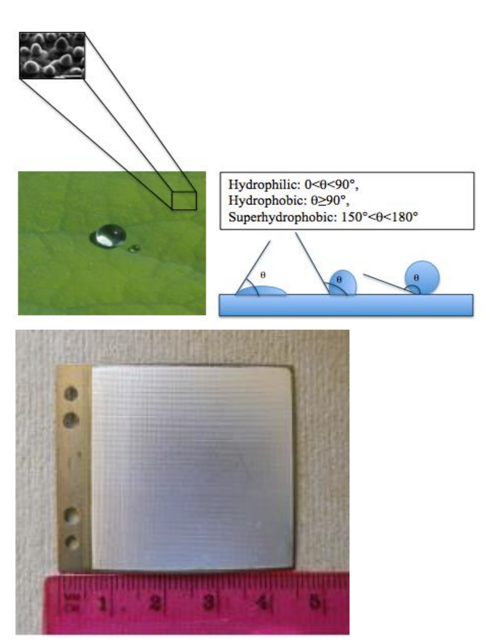




Superhydrophobic Materials

Electrospinning Apparatus:





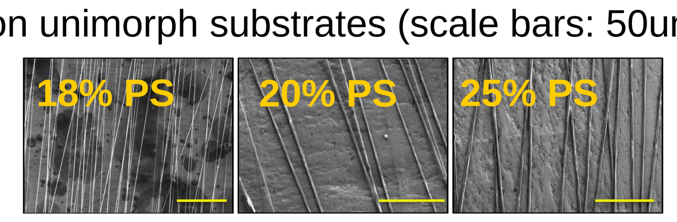
Background

- Superhydrophobic = hydrophobic + roughness
- Mostly chemical methods reported to apply roughness

Why electrospinning?

- Can produce micro and nano sized fibers.
- Can apply coatings to substrates of arbitrary geometry
- Can produced aligned and controlled structures

SEM images of electrospun polystyrene fibers on unimorph substrates (scale bars: 50um)



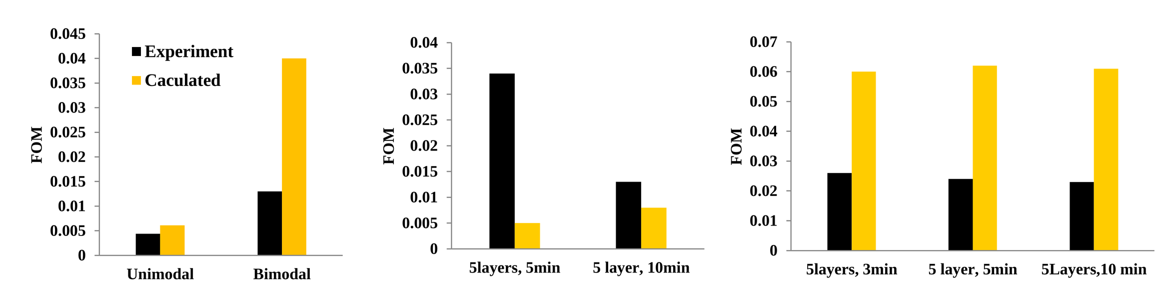
1. **Effect of electroactivation:** contact angles of coatings measured before and after electroactivation of piezoelectric substrate
2. **Effect of fiber spacing:** contact angles measured for coatings electrospun for various durations

Results

Performance of a filter is judged based on its Figure Of Merit (FOM) Q, which is a measure of filter pressure drop for a given collection efficiency.

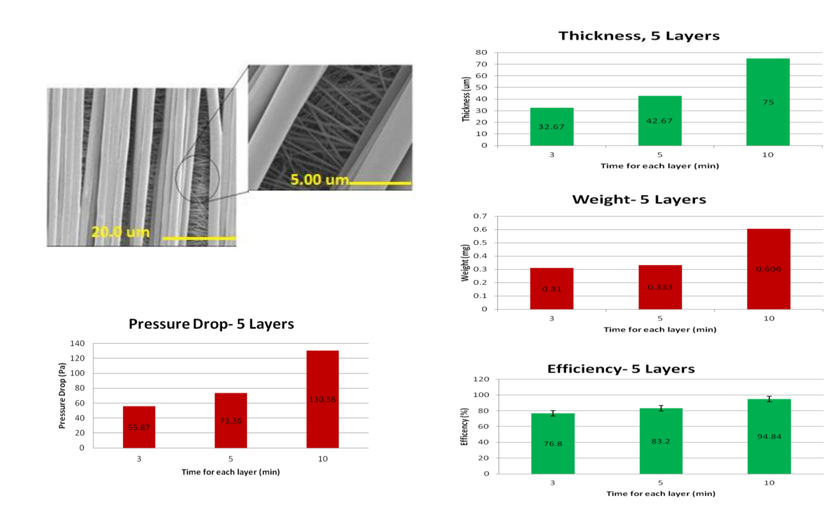
1) Comparing Unimodal and Bimodal of Random Fiber Configuration.
2) Comparing Unimodal Aligned Orthogonal Fiber Configuration.
3) Comparing Bimodal Aligned Orthogonal Fiber Configuration.

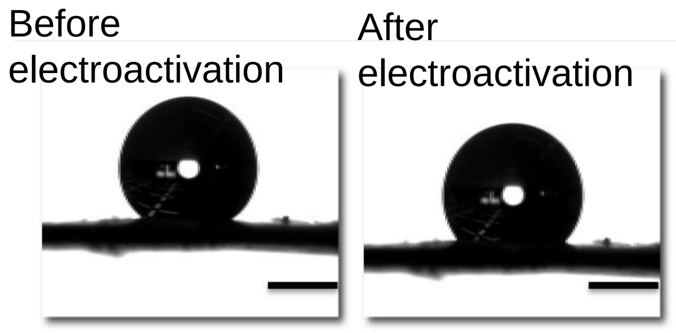
$$Q = \frac{-\ln(P)}{\Delta P}$$



Mismatch between experiment and Theory?
Non-uniformity of filter mats, Measurements error, and Nanoweb formation in Gap Method

Bimodal Orthogonal Fibers: The coarse fibers are 25% Polystyrene (toluene + THF 7:3) and have an average diameter of 1.6 µm. The fine fibers are 15% Nylon 4-6 (formic acid) and have an average diameter of 110 nm.





146.9˚ 130.9˚

$$\cos\theta^* = f(\cos\theta) + 1) - 1$$

Cassie-Baxter Equation

$$\cos\theta^* = r(\cos\theta)$$

Wenzel Equation

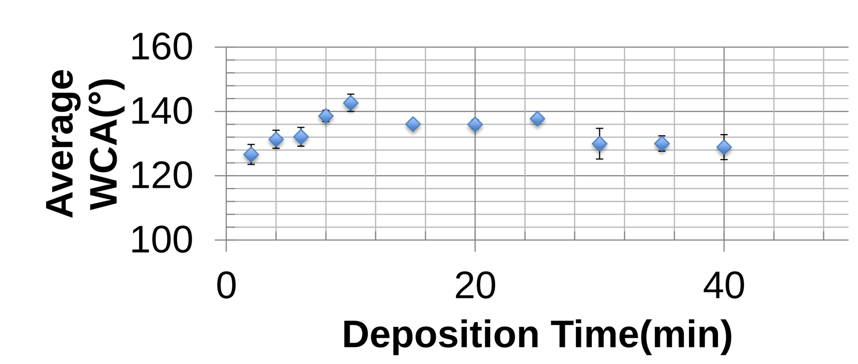


Table showing changes in WCA due to electroactivation

Solvent	% PS	Electrospinning Infusion rate (µl/min)	Electrospun fiber deposition time (min)	Average fiber Diameter (µm)	Average ΔWCA	Uncertainty at 90% confidence
Toluene/DMF	20	2.0	5	~3	9.6	±1.90
Toluene/THF	25	2.5	5	~2	7.2	±1.20
Toluene/THF	25	2.5	1-2	~2	2.5	±0.92
Toluene/THF	18	0.5-1.0	10	~1	3.5	±1.37

Discussion

- For the random bimodal mats the FOM is 200% higher than the random unimodal samples with the same basis weight.
- The performance of bimodal orthogonal fibrous mats was tested based on their solid volume fraction and ratio of the number of coarse to fine fibers.
- Samples with more layers will give higher FOM in comparison to those with lower number of layers.
- Analyses showed that using negative ions to discharge the samples during the electrospinning process will help the uniformity and also using two conductive strips to collect the fibers will enhance their uniformity.
- Comparison of the filtration performance of orthogonal fibrous mats (unimodal and bimodal) with the traditional random fibrous mats.
- Finally, making a conclusion on the relationship of the filter microstructure and filtration performance.

Acknowledgements

- NSF
- Contribution from group of students: Matthew Winkel, Gray Lawson, Sukhada Kulkarni, Samaneh Rakhshan Pouri, Brandon Dodd, Teresa Crenshaw

Discussion

- Water contact angle(WCA) of droplets decreased after electroactivation of substrate.
- WCA measurements indicating the behavior of coatings spun for durations between 2 and10 minutes are found to increase, in agreement with the Wenzel equation likely due to increase in roughness factor (r).
- In fiber coatings deposited for more than 10 minutes, WCA decreases with higher duration od deposition and shows agreement with Cassie-Baxter equation.
- An increase in fraction of solid in contact with liquid with deposition *(f)* is likely responsible.
- Increased adhesion also likely with higher fiber coverage and WCA decreases as droplets become less spherical and more spread out on the surface.